Hybrid Terrestrial/Satellite High Bandwidth Aeronautical Communication System

Overview

- **Data Communication Needs in Aviation**
- **Potential Benefits of Hybrid Terrestrial/Satellite Concept**
- **Hybrid Link Architecture**
  - **High Bandwidth Terrestrial Data Link Architecture**
  - **High Bandwidth Satellite Downlink Architecture**
- **Hybrid Link Operation**
- **Conclusion**

Data Communication Needs in Aviation

- **Data communications requirements rapidly increasing**
  - ATC, Homeland security, AOC, GA, and passengers
- **Current systems do not support bandwidth**
- **Current systems spectrally inefficient**
- **Desired new applications surpass capabilities of next generation upgrade plans**

Aeronautical Data Link Applications

- Traffic Information Services Broadcast (TIS-B)
- Flight Information Services Broadcast (FIS-B)
- Controller-Pilot Data Link Communications (CPDLC) and Digital Voice Communication
- Automatic Dependent Surveillance Broadcast (ADS-B)
- Homeland Security Applications
- Traffic Flow Management Applications
- Required Navigation Performance (RNR) for Terminal Area Navigation (RNAV)
- Support for Secure Operations (Key Distribution)
- On-demand Weather Products
- Aeronautical Operational Control and Administrative Communications
- Public Correspondence/Internet

Limitations of Current Upgrade Plans

- **Specialized upgrades**
  - VDL-Mode2
  - VDL -Mode3/8.33 KHz Analog (a.k.a Nexcom)
  - New private FIS-B provider communications systems
  - Mode-S/UAT/VDL Mode-4
- **Slow implementation and deployment**
  - Large equipage cost/small payoff for each upgrade
- **Substantial improvement, but limited capabilities**
  - Designs becoming obsolete
  - High bandwidth applications not supported

Next Generation "Next Nexcom"

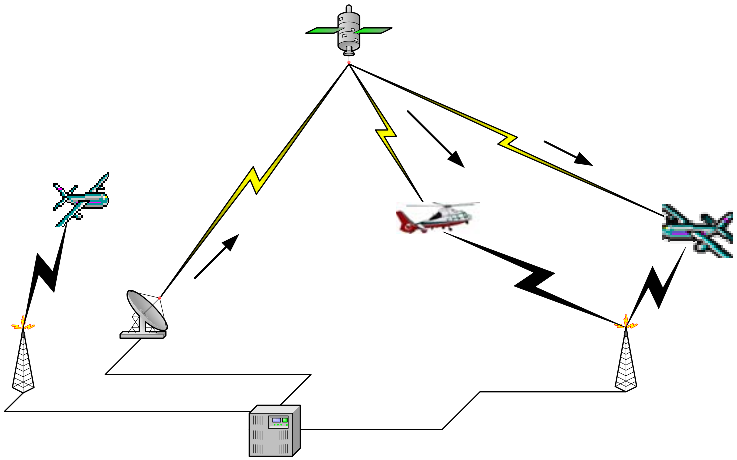
Requirements:

- Single consolidated avionics communications system
  - High bandwidth data and voice in a single link
- Much greater capacity
- Security
- NAS-wide reach, low latency
- High value/cost ratio

Proposed New System

Hybrid Aeronautical Communications System

- High bandwidth terrestrial link and satellite downlink
- Terrestrial link provides high bandwidth and low latency for local voice/data requirements
- Satellite link provides a NAS-wide, high bandwidth broadcast capability
- Hybrid operation provides on-demand data products over satellite link



Terrestrial Data Link Design

Terrestrial data link requirements include:

- Fit within the existing aeronautical bands
- High bandwidth capability (several MB/s minimum)
- High quality voice communications
- Low cost for potential users

Case study - 4G cellular service

- Orthogonal frequency division multiplexing (OFDM) modulation technology
- "Flash OFDM" design uses frequency hopping to allow sharing of spectrum with adjoining cell sites (frequency reuse pattern = 1)

High Bandwidth Terrestrial Data Link

Attributes of "flash-OFDM" systems being deployed today

- High quality of service, contention-free voice communication
- Simultaneously high-bandwidth data communications
- Much greater spectral efficiency than other modulation methods
  - Single 1.5 MHz channel to provide both wireless voice and user data rates up to several MB/sec. with delays < 35 ms
- Packet-switched, capable of using existing Internet protocols (TCP/IP)
- Improved multipath rejection and fading
  - Lower symbol rate results in lower intersymbol interference (ISI)

New terrestrial data link can use similar design

Terrestrial Data Link Spectrum

Alternatives within DME/SSR band (960 - 1215 MHz)

- Vacated DME channel - e.g., Universal Access Transceiver (UAT)
- Entire non-vacated DME band, on a non-interfering basis, using sidebands of the current DME system and frequency hopping
- UAT frequency
  - OFDM modulation and time access methods used to provide compatibility with existing UAT messaging
  - OFDM technique many times more spectrally efficient than UAT modulation

High Bandwidth Satellite Downlink

Design goals/constraints

- Service capable of > 1Mbit/second
- Coverage of North America
- Simple, low cost antenna for aircraft
- EIRP from existing C and Ku Band geosynchronous satellites too low

Case study

- Satellite Digital Audio Radio Service (SDARS) Providers, XM Radio and SIRIUS

SDARS Provider System Characteristics

	XM Radio	SIRIUS
Orbit	Geosynchonous at 85° and 115° West Longitude.	Inclined elliptical orbits with 2 satellites over the CONUS at all time (tundra orbit).
EIRP (dBW)	68	Less than XM, but the higher elevation coverage is expected to compensate.
Frequency Band	2332.5-2345 MHz	2320-2332.5 MHz
Elevation Angle	Average around 45° for CONUS, higher as you travel south.	Constantly changing, in most of CONUS one has an elevation greater than 60° and 2 in coverage.
Repeaters	Up to 1500 , 2kW repeaters	Up to 105, 40kW repeaters
Frequency Diversity	Satellites and repeaters are on different frequencies.	Satellites and repeaters on same frequency using different PN codes.
Spatial Diversity	Both systems use spatial diversity. The satellites and repeaters all broadcast the identical information.	
Time Diversity	Both systems use time diversity, satellites broadcast the identical data with a time separation between them. Protection against times when all satellites and repeaters are simultaneously blocked for short period of time.	
Modulation	QPSK	CDMA
Total Data Rate	Approximately 4 MB/sec. from each satellite	
Vehicle Antenna Gain	2-3 dBi	

Satellite Downlink Design and Spectrum

SDARS illustrate possible designs for hybrid link system

- Reliability suitable for ATC operations

Spectrum alternatives

- Aeronautical Satellite Mobile Services bands
  - 1545-1555, 1610-1626.5, 1646.5-1656.5 MHz
- Microwave Landing System (MLS) band
  - 5031-5090.7 MHz
- Strong possibility a SDARS provider may not survive

Hybrid Link Operation

Hybrid link architecture advantages

- Efficient operation with choice of nationwide or local coverage
- Terrestrial request channel operation for on-demand satellite delivery

Necessary bandwidth for consolidating many applications

- Consolidation lowers operating costs
- Consolidation requires application priority levels
  - ATC/TSA - high priority dedicated bandwidth
  - AOC/AAC - secondary priority

Conclusion - Consolidated and Expanded Services

Hybrid link system architecture attributes

- Design features driving down overall cost of avionics:
  - Consolidation of data services
  - Simple satellite antenna design
  - Radio designs similar to commercial systems
- Greatly enhanced services:
  - Guaranteed low latency access for system critical ATC applications
  - High bandwidth data and high quality voice
  - Secure operating mode
  - NAS-wide capabilities
- High benefit/cost ratio:
  - Quick adoption throughout NAS